High Level Waste Tank Seismic/Structural Analysis

WSRC Structural Mechanics
May 13, 2008

Introduction

- Analysis performed using guidance of:

  Tank Seismic Experts Panel (TSEP); Seismic Design and Evaluation Guidelines for DOE High Level Waste Storage Tanks (BNL 52361)

- Stress acceptance criteria:

  Concrete vault: ACI 349

  Steel tanks: ASME Section III Subsection NC-3200

Introduction

– Tank analysis divided into two independent elements:

  Concrete vault

  Steel tank

– Analysis concentrated on Type III tanks – results used to guide approach on other tanks

Vault Structural Analysis

- Evaluated for all operating/normal loads:

  Dead and live including loads on tank tops
  Fluid
  Earth pressure
  Annulus and tank internal pressures or vacuum
  Thermal
  Static settlement

Vault Structural Analysis

Natural Phenomena Hazards

- Seismic:
  - Tank fill height and viscosity variations
  - Fluid hydrodynamic behavior (slosh)
  - Soil-structural interaction (SSI)
- SSI required numerous variation:
  - Tank with top at grade
  - Tank in a hill
  - Tank to tank interaction

Vault Structural Analysis – Plan & Cross Section

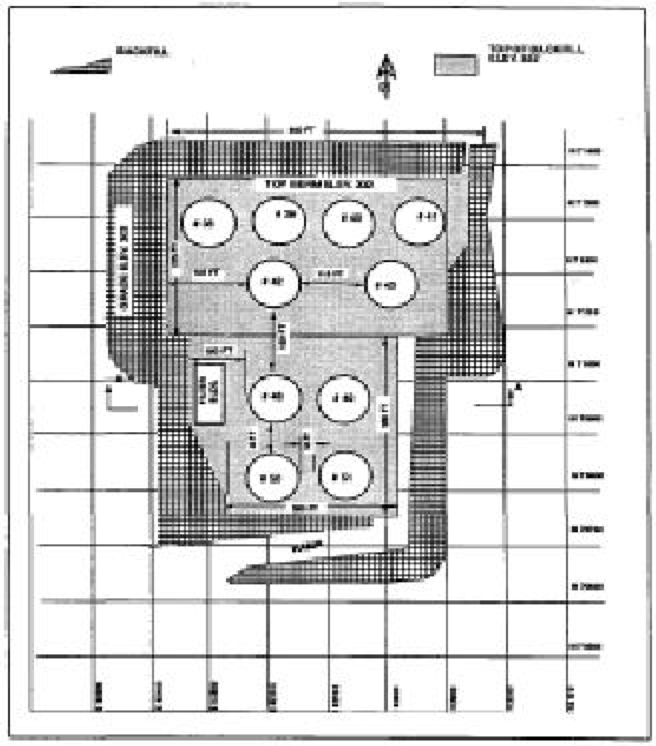


Figure 3.1 H-Area ITP Facility

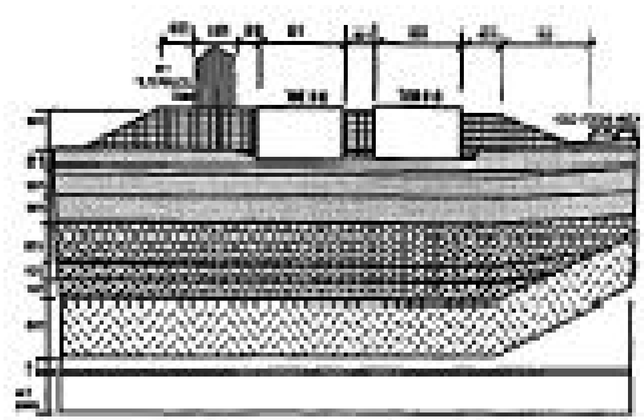
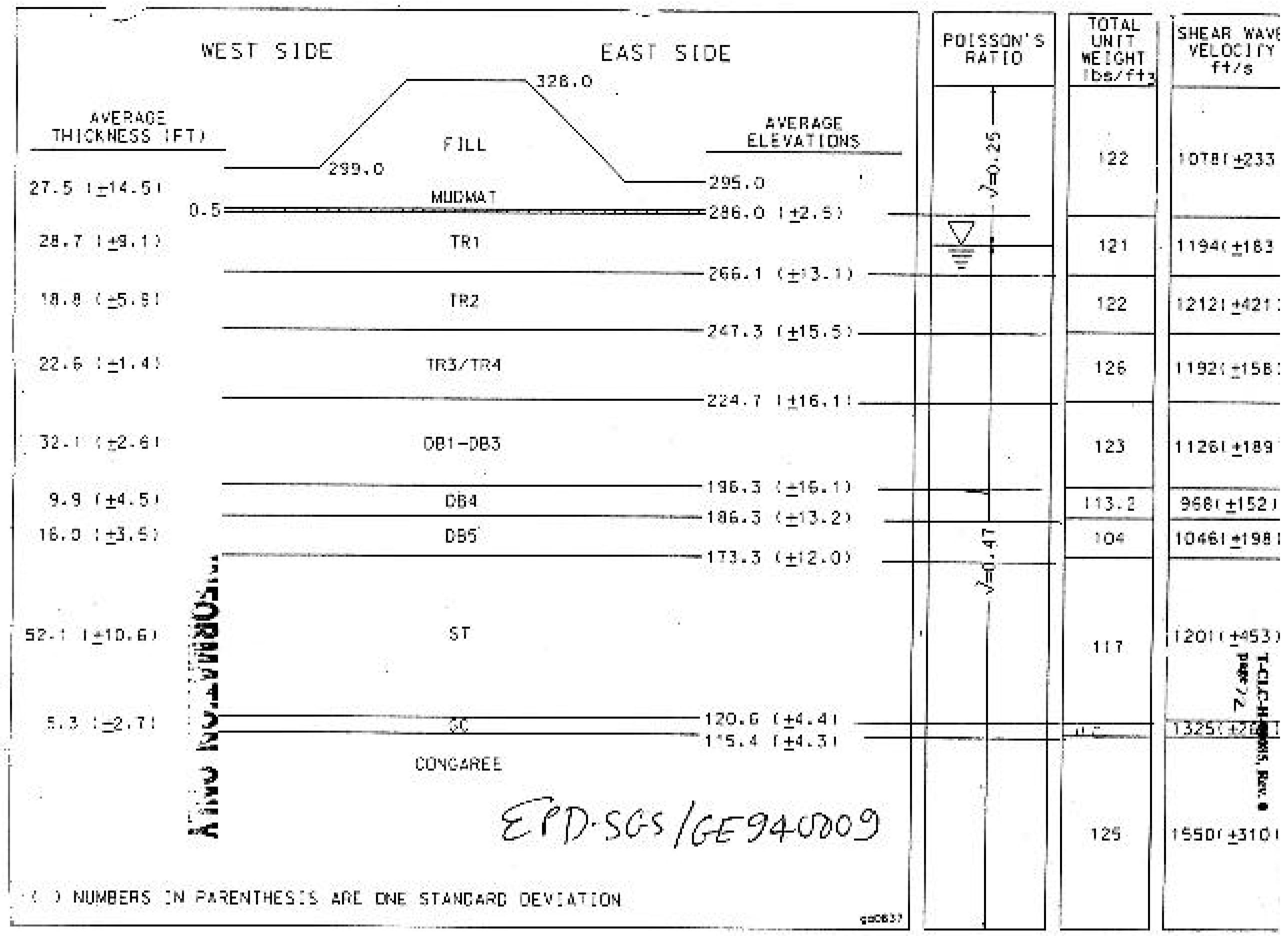
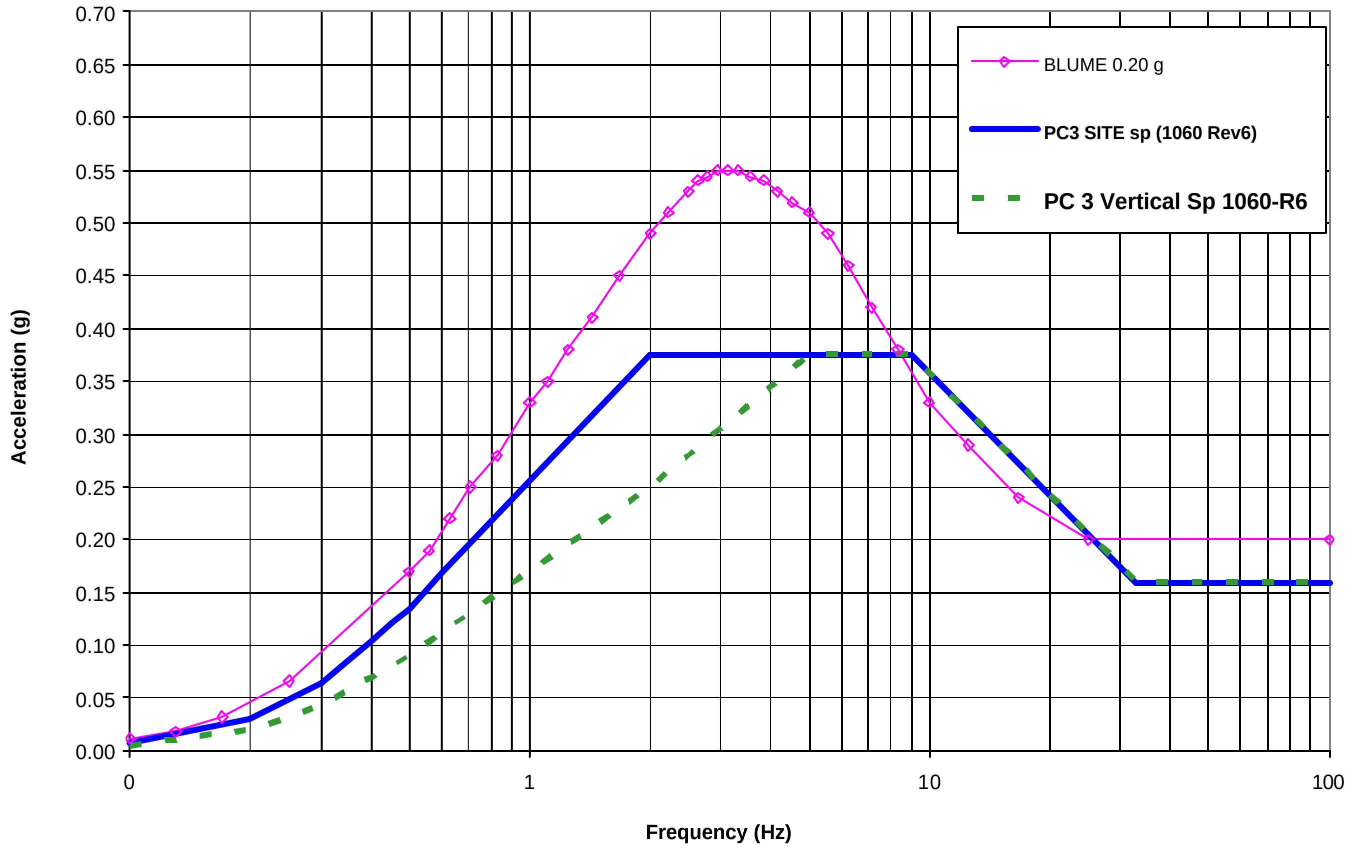


Figure 3.2 H-Area ITP Facility Section A-A

Vault Structural Analysis - Soil Profile



Vault Structural Analysis - BLUME vs. PC-3 Site Specific



Vault Structural Analysis - SASSI 3D Model

The stiffness of the secondary liner

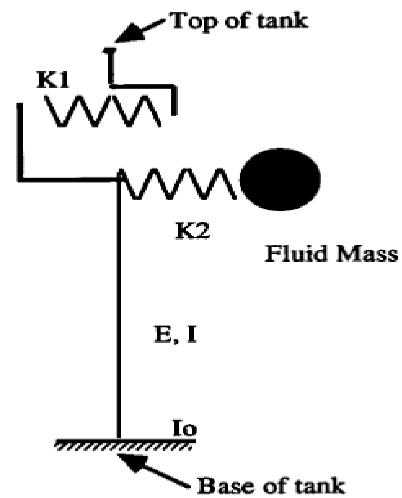
is included in concrete wall thickness.

Reinforced concrete

f'c = 3000 psi
Young's Modulus, E, = 450,000 ksf
Reinforcing Steel f_y = 60 ksi
Poison's ratio = 0.2
Density = .15 kcf

The secondary liner properties are:

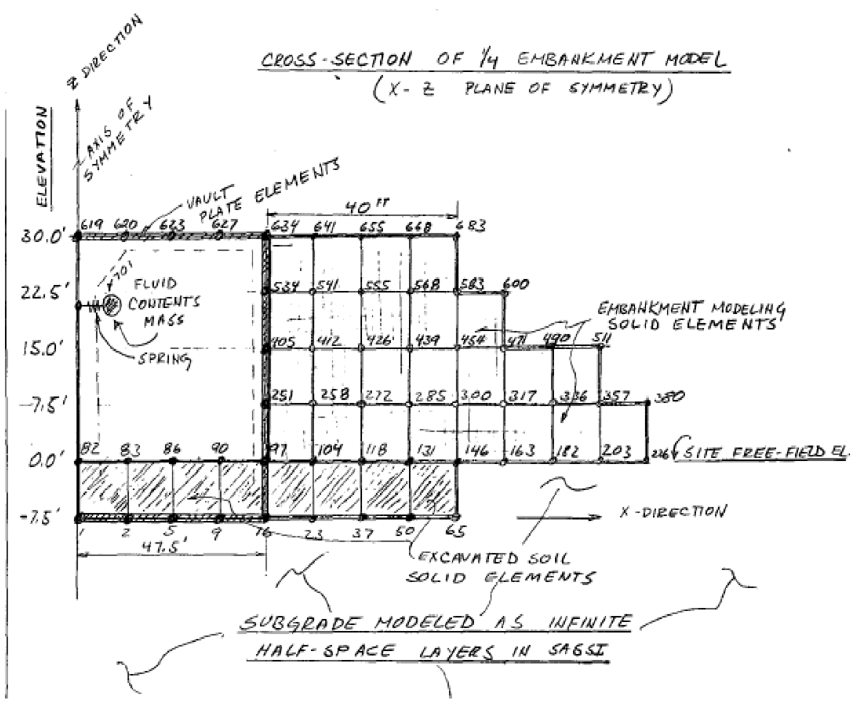
f_y = 38 ksi
E = 29,000 psi = 4,176,000 ksi
n= E/E_c = 9.3

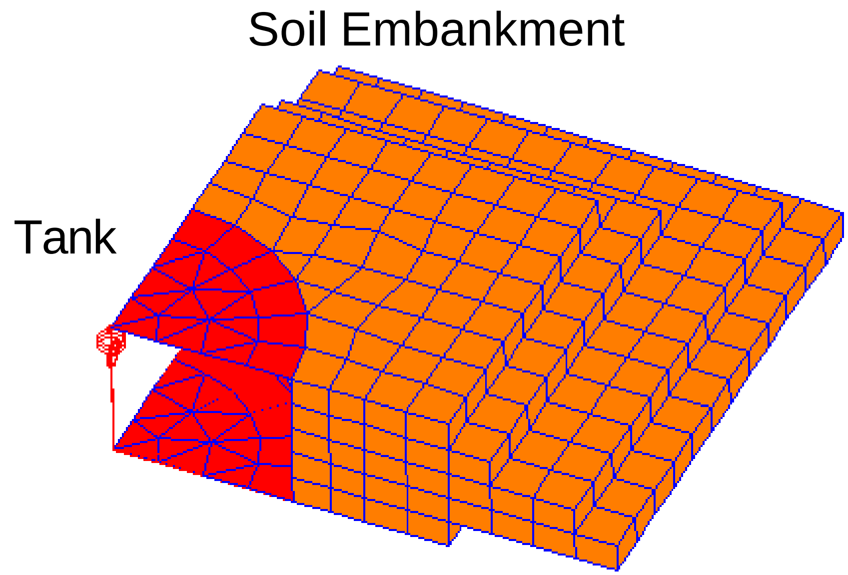


K1	=	1,040,000 k/ft
K2	=	520,000 k/ft
E	=	4,250,000 ksf
I	=	3208 ft^4
Fluid Weight	=	10,950 k
Io	=	1,246,040 (mass moment of inertia)

Stick Representation of Fluid using BNL 52361

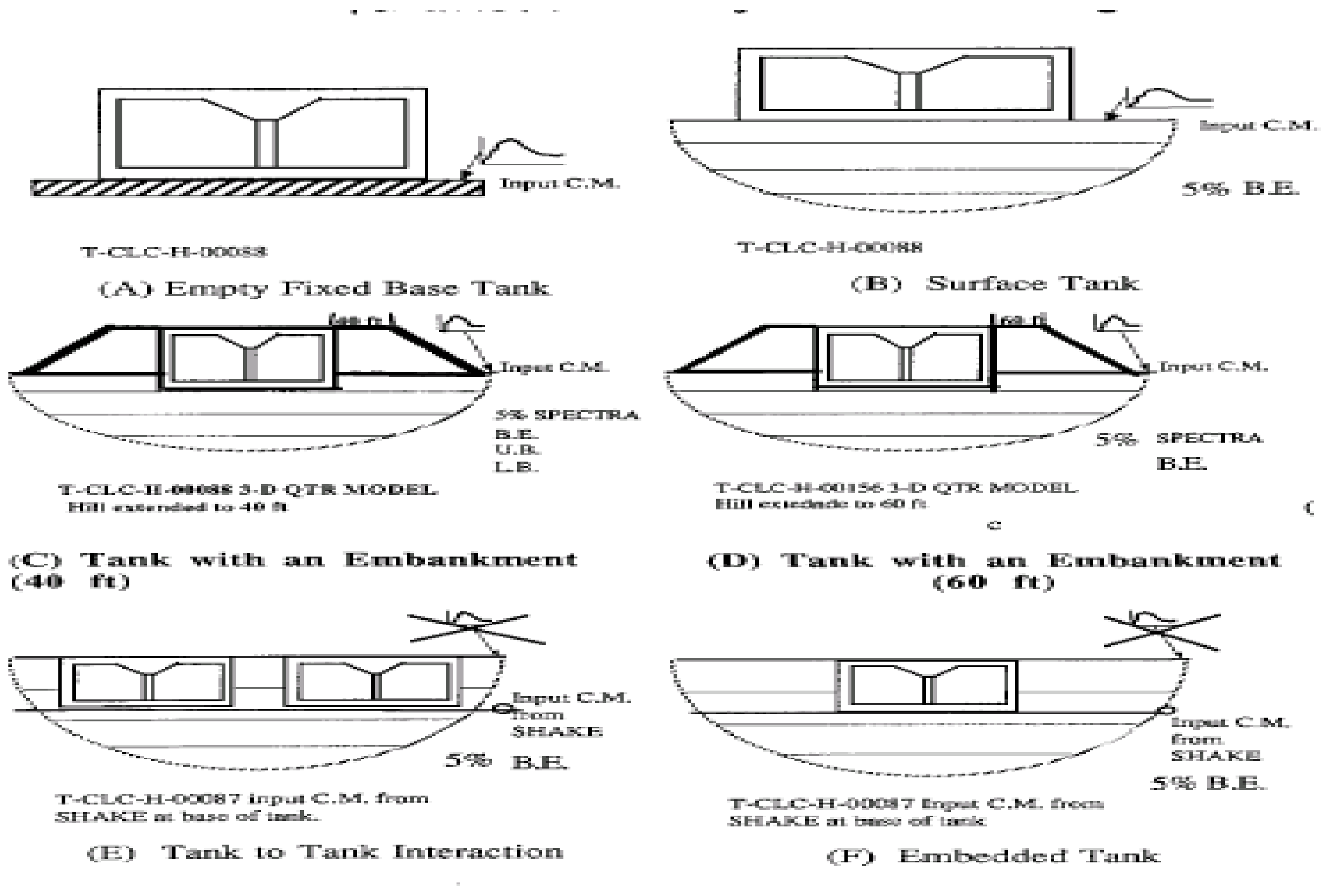
Vault Structural Analysis - 3-D Finite Element model of Tank and Soil Embankment





SASSI Model

Vault Structural Analysis - SSI Analysis



Vault Structural Analysis – Seismic Analysis Conclusions

- Normal operating loads met code allowable
- Tank top was marginal – tank top loads (additions/removals) are controlled under LWO program
- SSI had negligible effect – consequently analysis not performed for Type I and II tanks

Vault/Tank Structural Analysis - Differential Settlement

- Post seismic differential settlement resulting from:

  Partial liquefaction
  Collapse of subsurface voids
  Subsidence of soft zones

- Postulated as a surface subsidence of circular pattern of 95' diameter

  Design basis depth 1.75"
  Due to uncertainty: beyond design basis depth 3"

- Concrete vault and steel tanks evaluated separately using FEA (ABAQUS)

Vault/Tank Structural Analysis - Differential Settlement

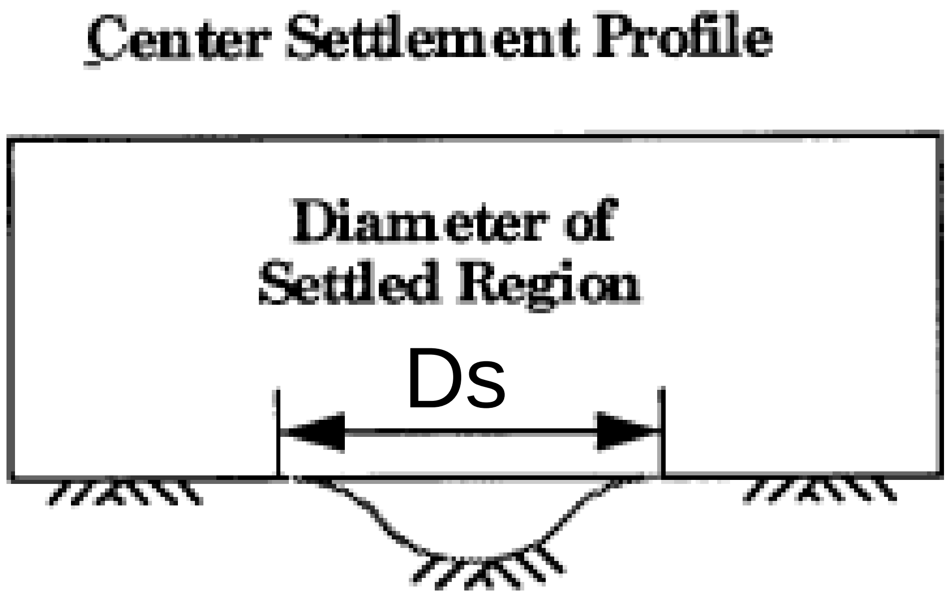


Figure 4.41

Vault/Tank Structural Analysis - Differential Settlement

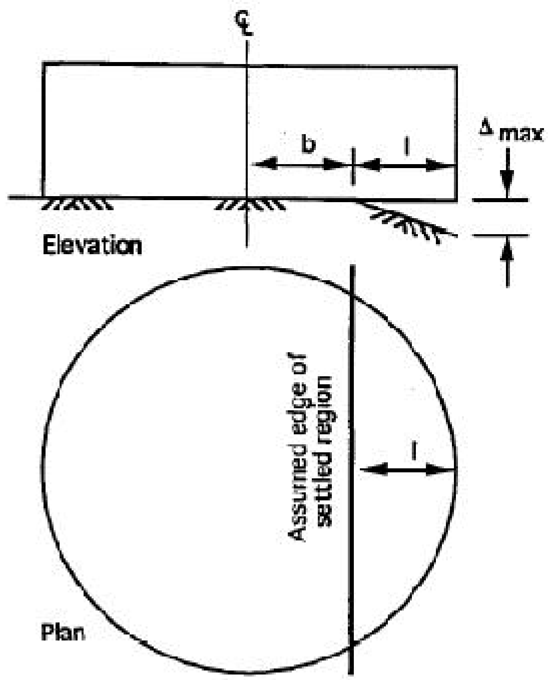


Figure 4.46 Edge Settlement Profile

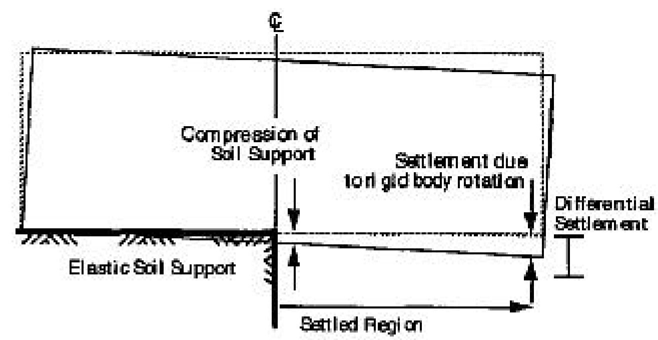


Figure 4.47 Rigid Body Rotation of the Vault due to Compression of Soil

Vault/Tank Structural Analysis - Differential Settlement

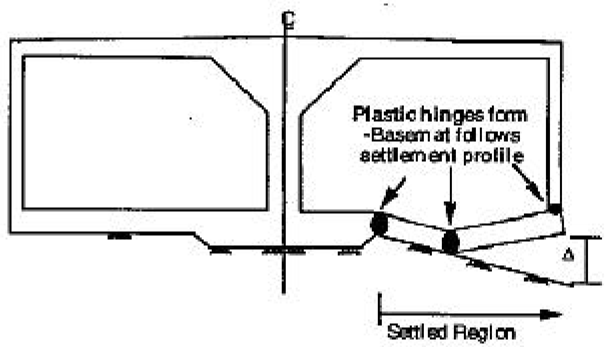


Figure 4.48 Cross Section Through Vault with Edge Settlement Profile and Possible Basemat Collapse Mechanism

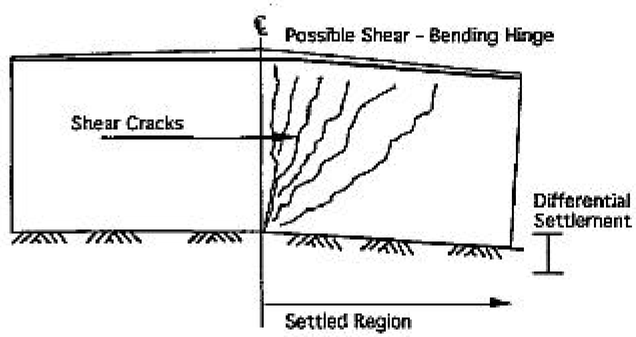
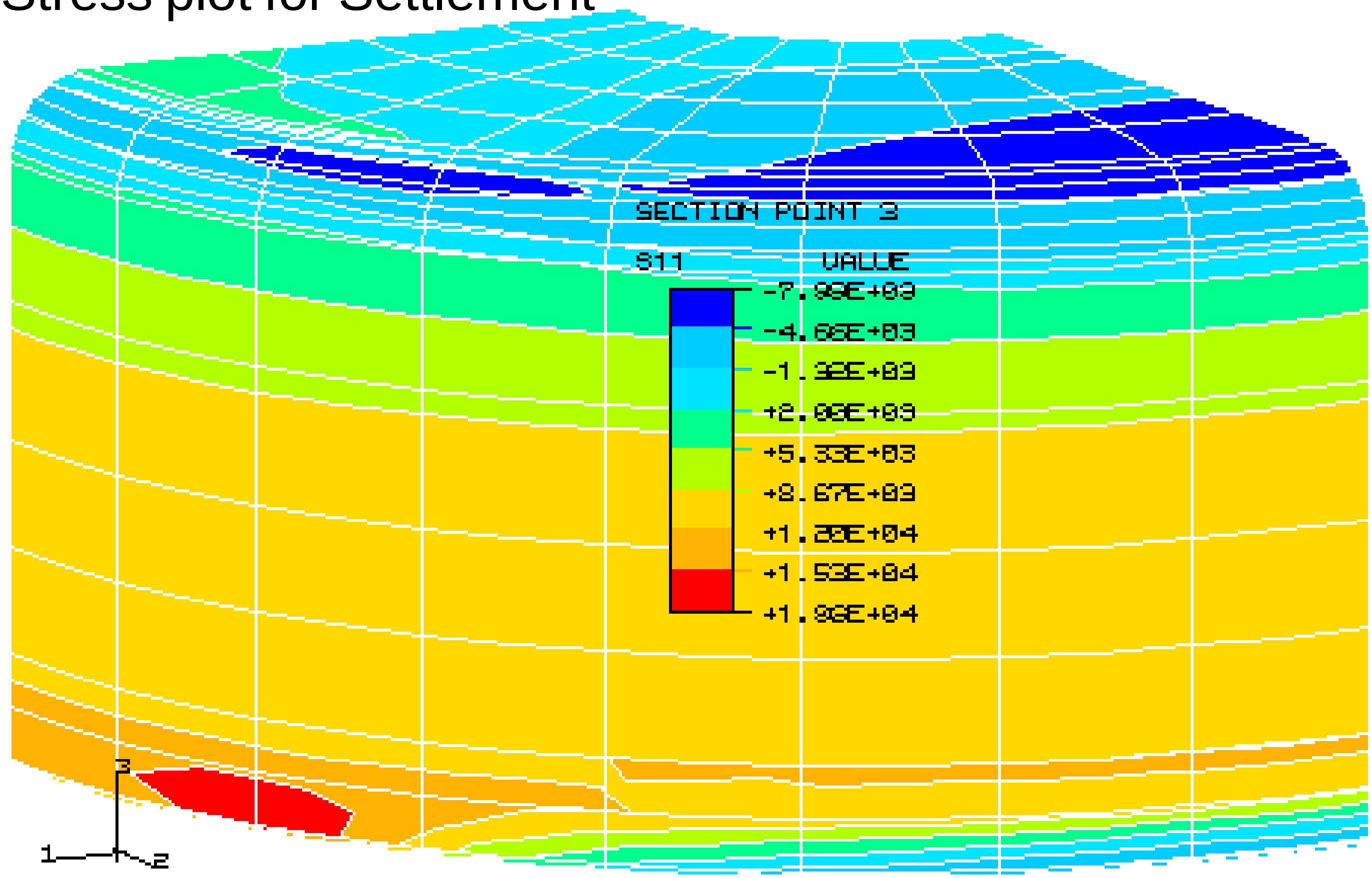


Figure 4.49 Vault Wall Shear and Bending Mechanism for the Edge Settlement Profile

Vault/Tank Structural Analysis - Differential Settlement

Tank Stress plot for Settlement



Tank Structural Analysis - Differential Settlement Results

Table 4.21
Steel Tank Allowable Soil Settlement for ITP Tanks and Type III Tanks

	Center Settlement	**Edge Settlement w/ Vault Wall Failure**	**Edge Settlement w/o Vault Wall Failure**
Vault Failure Mechanism	Base Slab and Roof Slab Failure	Failure of Base Slab, Roof Slab, and Vault Wall @ Vault Edge	Base Slab Failure Only
Figure No.	4.41, 4.44	4.42, 4.45	4.42, 4.48
Tank Deformations	14. in	1. in	6.6 in
Rigid Body Rotation	0. in	3.7 in	5.3 in
Maximum Allowable Differential Settlement	14. in	4.7 in	12. in
Stress Intensity Margin	0.0	1.4	1.4
Buckling Margin	0.43	-0.17	-0.17

Vault Structural Analysis - Differential Settlement Results

Concrete Vault “allowable” settlement

- Tanks 35 to 43 and 48 to 51: 5.1”
- Tanks 29 to 32: 5.5”
- Collapse occurs at settlement > 23”

Tank Analysis

FEA (ABAQUS)

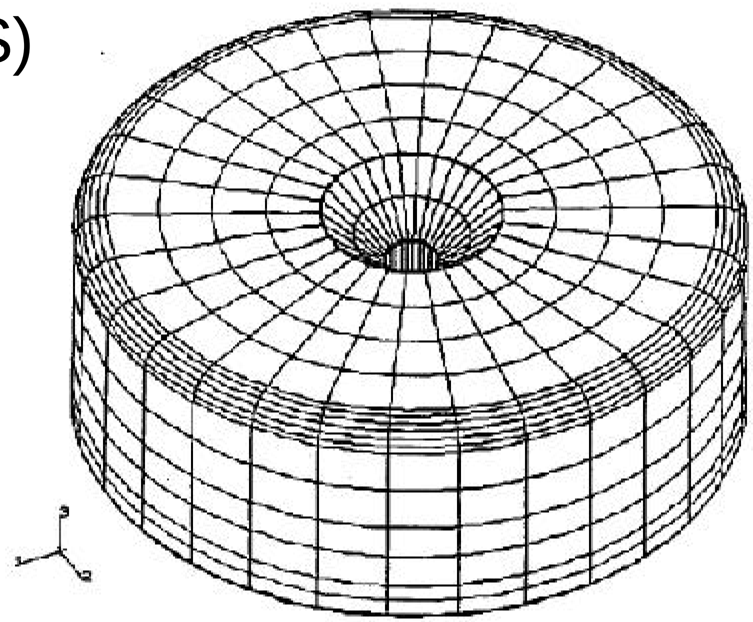


Figure 4.51
Finite Element Analysis Model

Tank Analysis

Determine Stresses from Normal Loads:

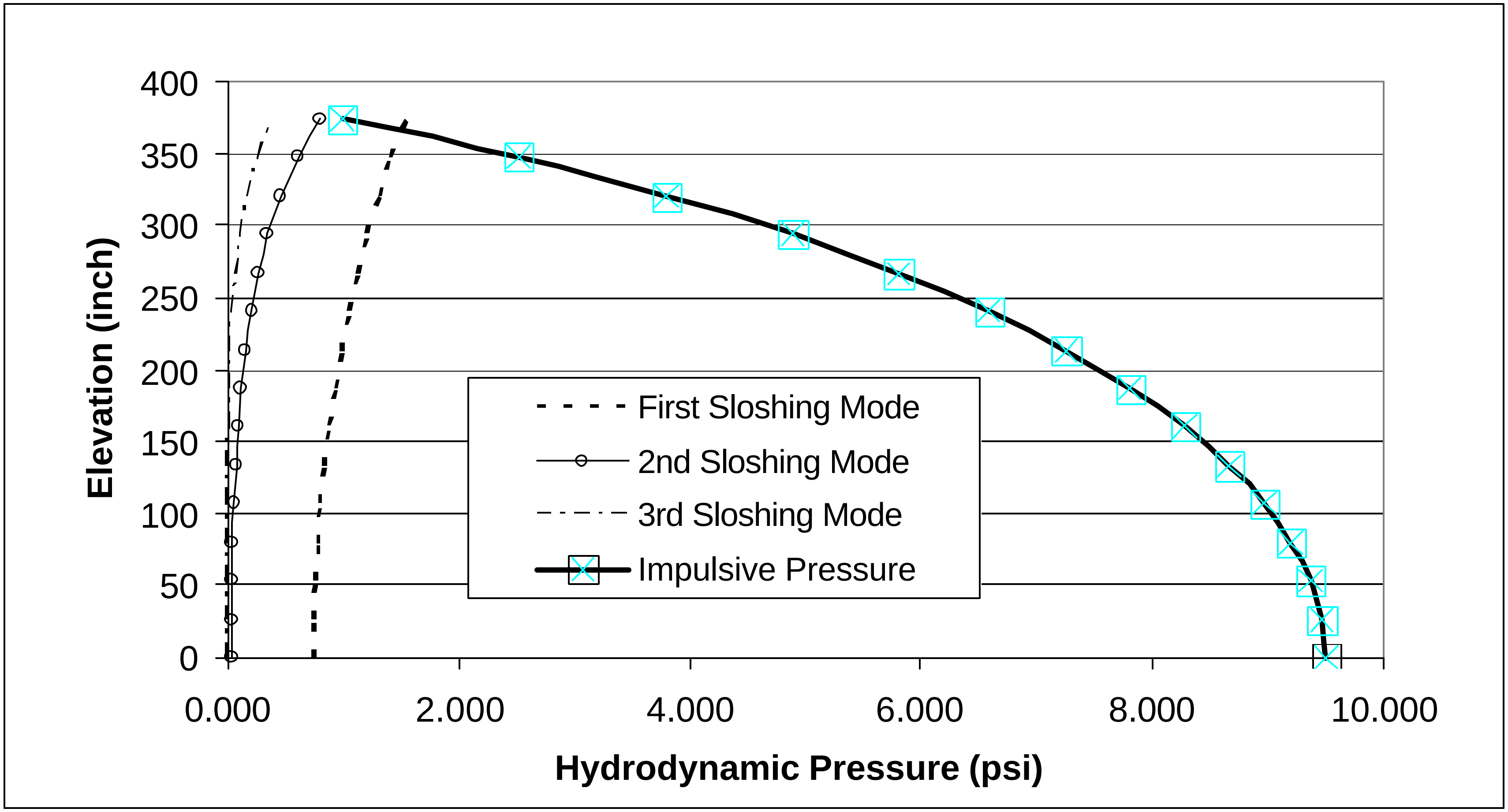
- Hydrostatic Fluid Pressure
- Annulus Vacuum/Pressure
- Tank Ventilation Pressures
- Jet impingement Loads
- Thermal Stress
- Salt loads on Tank wall

Tank Analysis

PC-3 Seismic Loads

- Horizontal Convective Mode
- Horizontal Impulsive Mode
- Tank Top Contact - Constrained Fluid Response
- Tank Top Contact - Fluid Impact
- Vertical Response Mode

Tank Analysis



Tank Analysis

- Compilation of FEA Results confirm that the tank stress condition can be computed, within 5%, by

$$Pr/t$$

- where:

  P = total Pressure contribution from fluid pressure, seismic pressures, and annulus pressures, (all hand calcs).

  r= tank radius

  t= wall thickness

Tank Analysis

Additional work that evolved from baseline analysis:

- Cooling cools loading
- Bottom pitting
- Dented walls
- Annulus vacuum
- Wall thinning

Tank Analysis – Wall Thinning Evaluation